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FORECASTING THE IMPACT OF NEW TECHNOLOGIES ON THE FUTURE JOB MARKET

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Abstract

This paper examines recent occupational projections in order to determine how new technologies will affect future job growth in the United States. The first part of the paper reviews the methodologies used to derive occupational projections, focusing on how adjustments for technological change are incorporated into the forecasts. The second part of the paper reviews the most recent projections produced by the U.S. Bureau of Labor Statistics and compares them with projections produced by other organizations. The results reveal that neither high-technology industries nor high-technology occupations will supply many new jobs over the next decade. Instead, future job growth will favor service and clerical jobs that require little or no postsecondary schooling and that pay below-average wages.

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New technologies are having a widespread and visible impact on work in the office, the factory, and even the farm. More and more workers, from managers to construction workers, are using computers in their jobs. Employment in engineering, computer specialties, and other technical fields is increasing, while employment in some traditional craft fields is declining. New job skills are emerging and some old ones are becoming obsolete.

This transformation is part of a continuing process of technological change that has been going on throughout the nation's history. Past technical developments reduced the labor requirements of farming and transformed work in the factory. Today's rapid developments in micro-electronics, biological sciences, and other "high tech" areas are transforming work in virtually all sectors of the economy.

This transformation promises renewed economic prosperity for the nation, but, at the same time, it may profoundly alter the nature of work in our society. It may stimulate economic growth and competition in the world marketplace, but it will displace thousands of workers and could sustain high unemployment for many years. It may provide increased job opportunities for engineers, computer operators, and robot technicians, but it also promises to generate an even greater number of low-level, service jobs such as those of janitors, cashiers, clericals, and food service workers. And while many more workers will be using computers, automated office equipment, and other sophisticated technical devices in their jobs, the increased use of technology may actually reduce the skills and discretion required to perform many jobs.

The promises and fears associated with technological change are not new. The Luddites in eighteenth century England smashed new loom machines because they feared the loss of their jobs. High unemployment during the Great Depression generated similar fears of job loss from technological development.

During the early 1960s the debate over the social and economic consequences of technological change once again became widespread. Unions were particularly vocal over this issue as more and more factories became automated and the national unemployment rate reached the fearful level of

6.8 percent. This concern prompted President Johnson to appoint a National Commission on Technology, Automation, and Economic Progress (1966). But as the commission debated the issue, the unemployment rate fell below 5 percent. The commission, as well as most of the studies that were done at this time, concluded that the fear of widespread and continued high unemployment was unfounded. Technological change affected some workers, industries, and areas of the country, but sustained economic growth would more than offset these losses and assure enough jobs for all workers somewhere in the economy.

Today the concerns over technological change have resurfaced. High unemployment and the rapid application of new technologies have raised the same questions that were raised by previous generations. Are these concerns largely unfounded as the previous concerns appeared to be?

Many people believe that high tech will provide substantial new job opportunities in occupations and industries associated with these new technologies, and that other workers will be using computers and other high-tech devices in their existing jobs. They contend that the sophisticated nature of these new technologies requires increased education and training to prepare for these opportunities. And finally they suggest that, while technology may eliminate some jobs, the sustained economic growth it will foster will provide plenty of new jobs to offset these losses.

Yet these beliefs may be based on a number of misconceptions about high technology. First, there is a widespread confusion between high-tech industries and high-tech occupations. High-tech industries--those industries engaged in the manufacture of computers, electronic components, and other technical devices--employ 15 percent or less of the work force in the United States. Moreover, less than a quarter of the jobs in these industries require substantial knowledge of technology, what may be called high-tech occupations. Most of the jobs in high-tech industries are in production and office areas that pay below-average wages. Neither high-tech occupations nor high-tech industries currently employ or are likely to employ more than a fraction of the work force in this country.

A second common misconception is that rapid growth rates for computer specialists, engineers, and other high-tech occupations translate into large increases in employment in these fields. In reality, most of these occupations employ relatively few workers compared to many traditional clerical and service fields. So even if employment in high-tech occupations expands much more rapidly than employment in other occupations, only a small fraction of the new jobs will be in these areas.

A final misconception is that future economic growth, spurred by high technology, will provide more than enough jobs to offset those displaced by machines. After all, the reasoning goes, past job losses in agriculture and manufacturing due to technological displacement were more than made up for by rapid employment growth in service industries. Why should the future be any different?

Yet history may tell us very little about the future. New technologies differ significantly from those of the past and therefore may have different impacts. Past technologies created new machines that greatly reduced the physical demands of work in agriculture, manufacturing, and construction. Future technologies, based on sweeping developments in micro-electronics, could greatly reduce the mental demands of work in virtually all sectors of the economy. The impact of these technologies is likely to be more widespread than that of past technologies because their cost has declined so sharply relative to their capability and relative to the costs of labor. The sharp reduction in price and the increased capacity of the computer provides the most vivid illustration of these developments.

Equally important, the economic context has changed considerably from the past. Unprecedented deficit spending levels and high interest rates have dampened the chances for sustained economic growth during this decade. Perhaps the biggest economic change, however, concerns the world marketplace. Technological advances in communications, transportation, and automated production have facilitated the movement of production facilities to all parts of the the world and created a worldwide marketplace for goods, services, and, most recently, labor. Japan, Europe, and an increasing number of Asian and Latin American countries now

produce products that compete with those from the U.S., even in state-of-the-art fields such as micro-electronics. The U.S. dominance of the world marketplace has now ended. U.S. workers now fear for their jobs, not just from other areas of the country, but from other areas of the world.

The unknown course of technical and economic developments makes it exceedingly difficult to anticipate their impact on future employment. Yet there is an important need to do so. If the educational system is to prepare tomorrow's workers, it must have some idea of what the future job market will look like. If government policy-makers wish to address potential disruptions from job displacement by providing effective retraining programs, they need to know which occupations will decline and which ones will emerge or grow. And if communities want to plan for their economic future, they need an indication of what to expect in terms of the structure of the job market.

While it is impossible to know precisely what the future job market will look like, it is possible to make useful projections on the pattern of jobs that are likely to be available. In a recent paper (Levin and Rumberger 1983) we examined projections for the job market in the year 1990 from the U.S. Bureau of Labor Statistics (BLS). We found that, although the percentage growth rate of occupational employment in such high-technology fields as engineering and computer programming was higher than the overall growth rate of jobs, far more jobs would be created in low-skilled clerical and service occupations than in high technology ones.

This report has been produced as part of a long-range study of high technology and labor markets. In this paper we will review the most recent employment projections by the BLS, for the year 1995, and compare them with those made by other organizations. We will also review the methodologies used in making the various projections. In subsequent papers we will examine the impact of technology on the number of jobs available in the future and on the skill requirements of future jobs.

Forecasting the Future Job Market

Before presenting and analyzing some recent forecasts of the future job market, it is important to address two questions that pertain to all

such forecasts. First, how should the accuracy of occupational projections be evaluated? Second, what are the appropriate techniques for deriving projections?

Accuracy

There are two criteria for judging the accuracy of particular occupational projections. One criterion is whether they provide better estimates for the use at hand than alternative methods, such as intuition, guessing, or simple extrapolations of existing trends. A second criterion is whether they meet the overall needs for the specific uses to which they are put. That is, even if they are the best projections among alternatives, there is a question of whether the errors are likely to be small enough that one can answer with reasonable confidence the questions at hand.

The answer to these questions depends upon the methodology underlying the projections and upon the uses to which the findings are applied. In general, sophisticated methodologies, such as those of the BLS, provide better estimates than extrapolation of existing trends or other simple techniques. In fact, as we will show, it is possible to evaluate systematically any biases in past BLS projections. The BLS has done this regularly as a basis for improving forecasting methods to reduce those sources of bias (Christy and Horowitz 1979; Carey 1980; Carey and Kasunic 1982). Other researchers have evaluated whether the costs of more rigorous approaches to forecasting are justified in terms of better policy decisions (Fishkind and Roberts 1978).

With respect to the uses of the data, it is easier to identify aggregate employment trends for broad categories of occupations--such as those jobs requiring high levels of skills versus those requiring low levels, or service occupations versus manufacturing occupations--than it is to estimate employment growth in a particular occupational area, such as fiber optics technician. The reason is that overall shifts in technology and products are more likely to create changes within the same occupational level. For example, what if there is a profound shift from shopping in stores to shopping by computer that is not anticipated by the forecasters? In that case, the projections will probably overstate the

growth in jobs for salesclerks and understate the growth in jobs for clericals. Since both jobs require only high school education, there is little or no bias in the projections for occupations requiring high school graduates, even though the composition of occupations within that aggregate is altered.

Thus occupational projections are better able to reflect aggregate trends than the absolute numbers of individual positions. If one wishes to know which occupations are likely to decline and which ones to grow as well as whether the growth or decline will be at a slow or rapid rate, the projections are likely to be more useful than if one needs accurate projections of the numbers of jobs that will emerge for narrow occupational classifications. In the analysis that follows, we will use forecasts for assessing trends and for comparing growth in occupations that require postsecondary schooling with those that do not.

Techniques

A number of techniques can be used to make occupational forecasts. Some techniques are simple and inexpensive; others are quite complex, involving a number of steps, and are therefore quite costly. One simple technique is simply to ask employers to identify their future employment needs. This technique has been used to project future needs for engineering and computer personnel in the electronics industries (Hubbard 1981). Another simple technique is to extrapolate present employment needs into the future based on past trends. For example, projected needs for scientific personnel could be derived from information on present employment in these areas and expected growth in the industries where such workers are employed.

More sophisticated techniques attempt to account for a larger number of factors that might influence future employment opportunities. Most of the more comprehensive approaches are based upon elaborations of the following relationship (Fechter 1975, p. 11):

Employment = Output x Labor/Output x Employment/Labor.

This relationship simply says that the future employment requirements in any particular occupation can be estimated from projections of future output, the total labor required for each unit of future output, and the number of persons employed in that occupation per unit of total labor. Although this basic framework is straightforward, its application requires a complex evaluation of the expected output, employment, and occupational requirements for every industry of the economy, as well as adjustments for changes in technology, productivity, and other factors.

This technique does not consider how changes in relative prices among categories of labor and capital might result in substitution between these two factors of production. The effects of substitution can be captured through adjustments in the labor/output and occupation/labor ratios, but these adjustments are normally made in an ad hoc fashion, not through an explicit price model.

This approach projects the total number of jobs that will be available in the future, not the number of job openings. The number of job openings due to death and retirement is two to three times greater than the number of openings due to employment growth (U.S. Bureau of Labor Statistics 1982, p. 9). An even greater number of openings arise from turnover. Replacement needs are generally higher in low-paying jobs, since they experience more turnover than higher-paying ones. Thus, employment projections will understate future job openings for all jobs, but more so for the lower paying ones requiring the least education.

The more elaborate the forecasting technique, the more refined will be the method for estimating each of the variables in the relation set out above. For example, economic growth for the economy, the composition of output among goods and services, changes in production techniques and other technological impacts will affect each of the determinants. The most comprehensive techniques attempt to take account of all of these concerns, while the simple ones do not.

All projection techniques, no matter how sophisticated, require some assumptions about the future economy and labor market. The assumptions attempt to anticipate what the future will look like. Some are simply based on extrapolations of past trends. For example, if labor

productivity (output/labor) increased at an average annual rate of 3 percent over the last 20 years, then this same rate of growth might be assumed to continue into the future. More sophisticated techniques make assumptions about future conditions on the basis of systematic adjustments, rather than relying on simple extrapolations. Yet even the most sophisticated techniques cannot anticipate some of the factors that might influence future job growth, such as war and economic recessions. All projections therefore assume that economic and political conditions will be relatively stable over the period of the forecast.

One way of dealing with future uncertainties is to construct a series of alternative assumptions about future conditions. These alternative scenarios can then be used to construct alternative forecasts. For instance, one forecast might be based on assumptions of faster economic and productivity growth rates and another based on assumptions of more modest growth rates.

Occupational forecasts that try to account for the impact of technological change are particularly difficult to make. Even if forecasters limit their analysis to evaluating the impact of technologies that exist at the time the forecasts are made, it is still extremely difficult to determine the speed and the particular manner in which technologies will affect the future job market. This problem is even more difficult today because of the rate at which advances in micro-electronics are taking place and the potential use of technologies based on these advances throughout the economy.

Most forecasters acknowledge, for example, that robots will be used more widely in our future economy. But it is much more difficult to project future employment needs for robot technicians because no one knows just how fast and how widely robots will be introduced into the economy. Moreover, as robot technologies become more fully automated, labor requirements to build robots will likely decline. Simple projection techniques based on anticipated needs or simple extrapolations make little or no attempt to account explicitly for the diffusion of technology throughout the economy and, therefore, provide limited information on future job requirements related to new technologies.

The ability to accurately project the impact of technology on the future job market depends on the time horizon over which the projections are made. Short-term projections, covering a period of several years, are less likely to deviate from current trends, although they are still subject to the effects of unanticipated events such as economic downturns. Long-term projections are more difficult to make, especially in areas related to new technologies. For this reason, most long-term projections are limited to periods of 10 or 15 years. The BLS revises its projections every two years to account for these changes and to provide feedback to the forecasting process on improving adjustments for technological change and other factors (Andreassen, Saunders, and Su 1983, pp. 12-13).

While all comprehensive forecasts of occupational growth or decline use the same general techniques, differences in particular techniques and in assumptions about the future economy can lead to different results. A review of the particular techniques used by the BLS and other agencies illustrates these differences.

BLS Projections

Since the 1940s the BLS has produced the most widely used and comprehensive occupational projections in the United States. Projections are made for a 10 to 15 year period, targeted on the beginning or middle of the next decade. The BLS has developed an elaborate methodology and provides forecasts for the entire economy rather than limiting its efforts to particular occupations. It has systematically evaluated the accuracy of its own projections over time and used these evaluations to improve its methodology. The latest projections, which cover the period from 1982 to 1995, will be examined in detail in the next section of the paper.

The BLS derives its projections from the basic model described above, where occupational requirements are estimated for each industry based on projected output growth, growth in labor productivity, and the occupational composition of each industry. These requirements are then aggregated to produce occupational requirements for the economy as a whole. Over the years this basic methodology has been improved and more accurate data have been collected to improve the relative precision of the projections. For instance, the BLS now uses data on occupational

requirements in industry from surveys specifically designed to collect that information, rather than from the decennial census that was used in the past. The BLS now makes several occupational projections based on alternative economic scenarios rather than a single projection.

The methodology that is currently used to make projections includes a number of distinct steps (Oliver 1982, p. 1):

1. Projecting the size of the future labor force;

2. Projecting aggregate economic output with a macro-model;

3. Disaggregating the projected GNP into detailed demand categories;

4. Distributing each demand category into detailed, producing industries;

5. Projecting an I-O (input-output) table to distribute intermediate products among industries;

6. Projecting productivity, hours, and employment for each detailed industry;

7. Projecting an industry-occupation matrix for each industry to derive occupational employment by industry;

8. Aggregating occupational employment across industries to derive total occupational employment within the economy.

In the current estimates, three sets of assumptions regarding economic growth and inflation are used in step 2, yielding three sets of occupational forecasts.

There are two places in this process that the BLS attempts to account for the impact of technological change. One is in step 5 where adjustments are made for anticipated changes in the input requirements of

each industry. For instance, the increased use of plastics and the decreased use of steel in producing automobiles would affect the demand for the products from these two industries as well as the employment generated in them. The second is in step 7 where adjustments are made for anticipated changes in the occupational composition of an industry due to the use of new technologies. In the automobile industry, for example, the increased use of robots would lower the labor requirements for operatives, who are replaced by the robots, and raise the requirements for robot technicians.

Evaluations of past projections reveal that the BLS has been more successful in identifying how emerging technologies are likely to affect future job growth than in ascertaining the speed with which such effects are likely to come about. In the 1975 projections, for instance, the BLS correctly identified the laborsaving effects of technologies related to the employment of knitters, weavers, telephone operators, and several railroad occupations (Carey 1980, p. 19). But it did not anticipate the rate at which these new technologies would be adopted and the resulting employment declines for telephone operators, railroad engineers, and brake and switch operators. And while employment declines for weavers, knitters, and locomotive engineers were anticipated, they were understated. An evaluation of the 1980 BLS projections yields a similar conclusion (Carey and Kasunic 1983, p. 24): "the BLS has been more successful in identifying employment growth than employment declines and where they have correctly identified employment declines, they have often underestimated the rate of decrease."

At the other extreme, the BLS has tended to <u>overstate</u> the employment growth in some technical fields, especially engineering (Goldstein 1983, p. 56). In general it appears that past projections have overstated the growth of technical occupations and understated the decline of certain traditional jobs.

Overall, however, the BLS projections have been fairly accurate. Comparisons between actual employment levels and projected employment levels for detailed occupations reveal an average absolute error of 21 percent for the 1975 projections and 22 percent in the 1980 projections.

When weighted by the level of employment in each occupation, the average absolute error declines to 14 percent in both years (Carey 1980, p. 14; Carey and Kasunic 1982, p. 23). In a recent evaluation of the BLS projections, Goldstein (1983, p. 55) found that 80 percent of BLS forecasts for detailed occupations in 1975 were within a 10 percent range of actual employment levels for that year and 60 percent of the 1980 forecasts fell within that range. The poorer performance in the more recent forecasts may indicate an increasing difficulty in anticipating the future impact of technological change as well as the sharp changes in the fortunes of the economy. The estimates for 1995 have attempted to accommodate more fully adjustments for a range of assumptions that might reduce such errors.

NSF Projections

As part of its concern with scientific and technological activities in the U.S., the National Science Foundation (NSF) provides information on the market for scientific and technical personnel. This information includes projections of the supply of and requirements for scientists and engineers. In the 1950s and 1960s, the BLS derived special projections of scientific and technical jobs for the NSF. Beginning in the late 1960s, NSF began to develop its own projections for doctoral-level science and engineering personnel. Earlier projections were made for the years 1980 and 1985, based on data for the years 1968, 1969, and 1975. The most recent projections for science and engineering doctorates were made for the years 1982 and 1987 (NSF 1979). In 1983, NSF published projections for 1987 that include all science, engineering, and technician personnel (NSF 1983).

The NSF extrapolated trends in undergraduate enrollments to project academic requirements for science and engineering personnel and trends in research and development funds to project industry requirements for these personnel (NSF 1979, pp. 29-30). These rather simple techniques have been quite satisfactory in estimating requirements for these particular occupational areas, especially when employment is concentrated in only a few sectors of the economy. Recent results compare favorably with those developed by the BLS (NSF 1979, p. 32).

In the latest projections, NSF used a much more sophisticated, multi-step model similar to the one used by the BLS. The basic model, referred to as the Defense Interindustry Forecasting System (DIFS), is a commercial version of a model developed by the Department of Defense and Data Resources, Inc. to analyze the economic impact of defense spending on the U.S. economy (Dale 1983, p. 161). Some steps of the model--such as the macro-economic forecasts and the interindustry relationships--differ from those developed by the BLS, while other components--specifically, the occupational staffing patterns within industries--are based on the BLS model.

As with the BLS model, there are two places where the impact of technological change can be assessed: in the interindustry relationships, and in the occupational staffing patterns. Since the latter component comes from the BLS, only the former component is likely to yield any different projections with respect to technological change. But since the model is not really designed to address this factor, it is unlikely to provide any better assessment of the impact than can be derived from the BLS projections. The advantage of this model is that it assesses the requirements for scientific and technical personnel based on alternative assumptions about the growth of military spending as well as on alternative assumptions about economic growth.

IEA Projections

The Institute for Economic Analysis (IEA) at New York University has recently completed an economy-wide projection of occupational employment for the years 1990 and 2000 (Leontief and Duchin 1983). These projections, based on the pioneering work of economist Wassily Leontief, demonstrate an alternative way of trying to assess the future impact of technological change on employment.

The basic model used to derive these projections is similar in some respects to the model used by the BLS. In fact, the basic macro-economic projections and much of the data come from the BLS and other government agencies. But the IEA model differs from the BLS in several important respects. First, it models the relationships between industries in a dynamic fashion, estimating changes in those relationships on a yearly

basis instead of using a single adjustment for the entire projection period as done by the BLS. The most recent BLS estimates, for example, are based on 1972 interindustry relationships that are then adjusted for the year 1995. Second, the IEA accounts for changes in the capital requirements--both replacement capital and expansion capital--related to several new technologies, such as computers, robots, and office automation equipment. Third, the IEA model uses projected labor requirements for this new capital to derive occupational employment rather than using industry staffing patterns.

A specific example can illustrate the application of the IEA model. One impact of the increased use of computers in production is through the use of computer-aided design (CAD) equipment, which reduces the requirements for drafters. Two of the three scenarios used in the IEA projections assume increased rates of diffusion of this technology and hence different rates at which drafters will be displaced. One scenario assumes that the requirements for drafters will be greatly reduced by the year 2000, while the other scenario assumes that all drafters will be eliminated (Leontiff and Duchin 1983, p. 4.19). Similar techniques are used to project employment growth in industries producing new technologies, such as computers, robots, and office automation equipment, and to project employment declines in industries where the technologies are used.

The IEA model makes an explicit attempt to account for the impact of technological change on employment. While the BLS does attempt to account for that impact, the adjustments to interindustry relationships and occupational staffing patterns are generally ad hoc and the assumptions underlying them are not published systematically. The IEA model also incorporates personal judgements about the probable impact of technology, but many of the assumptions and information underlying those judgements are described explicitly.

In order to account for different rates of diffusion of new technologies, the IEA projections contain three different scenarios. One assumes no further technological changes after 1980, only increased demand based on the relationships that existed in that year. The other two

scenarios assume increased diffusion of technical devices throughout most sectors of the economy and changing labor requirements associated with their use.

The IEA model is the first economy-wide model specifically designed to forecast the impact of technological change on future employment. It also is the first to provide alternative scenarios based on different assumptions about the rate of diffusion of technology. Despite these improvements, the IEA model still does not address other factors likely to affect future employment. It does not address technological advances that could affect production and labor requirements in the agricultural, telecommunications, and publishing fields (Leontief and Duchin 1983, p. 1.28). Nor does it examine possible changes in foreign trade and production that could also produce significant changes in domestic employment (Bluestone and Harrison 1982, pp. 42-46). The resulting estimates may be more dynamic and realistic than those produced by the BLS, but they still may not go far enough in assessing how technological change throughout the economy may affect the future level and composition of employment in this country.

Other Projections

The Department of Defense has projected occupational requirements in a number of areas based on anticipated defense spending. These projections are based on the same model as the recent NSF projections described above. In addition to occupational areas, the projections examine demands on particular industries (Dale 1983).

Other projections concentrate on the future needs for specific occupations. The National Center for Education Statistics (1982) provides projected requirements for teachers based on expected trends in the school-age population. The American Electronics Association recently projected needs for engineers and computer specialists in the electronics industry (Hubbard 1981). These projections, while useful to individuals and organizations concerned with the future needs in these fields, provide little information about the overall impact of technological change in the future economy.

The Future Job Market

Although employment in particular occupations may change rapidily in the future, recent projections indicate that employment in major industrial and occupational categories is likely to follow past trends. Over the nation's history, the economy has been dominated by several key industries. Agriculture was the primary economic activity in the nation's first one hundred years. Even as late as 1900, 4 out of 10 workers in the U.S. were employed in agriculture (Table 1). But by that time the majority of workers were employed in two other areas, goods-producing industries--mining, construction, and manufacturing--and services-producing industries--transportation, public utilities, trade, finance, insurance, real estate, services, and government. Agricultural employment has declined steadily and quickly since the turn of the century. By 1980 only 3 percent of the work force was employed in this sector. Employment in goods-producing industries has remained fairly constant during this period, while employment in service industries has grown tremendously--from 31 percent of the workforce in 1900 to 69 percent of the work force in 1980.

These changes have shaped the composition of jobs in the economy. Employment in farming occupations declined as the farming industry became a less significant employer (Table 2). The constant share of employment in goods-producing industries has maintained jobs related to those industries, particularly craft and operative occupations. The growth of service industries has spurred employment in occupations related to these areas, particularly professional and technical, clerical, and other lower-level service jobs such as custodians, waiters, and cashiers. To a lesser degree, shifts in the composition of occupations within industries, such as the increasing proportion of clerical and managerial occupations within manufacturing firms, have also altered the composition of employment within the economy.

Employment projections for 1995 indicate that these past trends will continue. Both the long-term trend of declining employment in agriculture and the more recent trend of declining employment in manufacturing will continue in the future (Table 1). Employment in service industries will

continue to increase. Employment in other sectors will change little or not at all. Employment within major occupation groups will also change very little. The proportion of the work force employed in professional and technical, sales, and service jobs will increase slightly, while employment in managerial, craft, and operative areas will decline slightly. The increased use of new technologies will do little to alter the composition of employment among major industrial and occupational categories.

Yet more dramatic shifts in employment will take place in detailed industrial and occupational categories. How will technology influence employment growth within particular occupations and industries? The BLS and other recent projections can help answer such a question.

Before proceeding, it is important to emphasize the difference between high-technology industries and high-technology occupations. The growth of high-technology will increase employment in those industries where high-technology products--such as electronic components and computers--are manufactured. It will also spur employment growth in those occupations related to the design, development, manufacture of such equipment as well as in occupations where the equipment is used. We will use the BLS projections to evaluate the employment impact of high technology on both industrial and occupational employment. But in order to assess education and training requirements in the future job market, we focus primarily on occupational projections.

BLS Projections

In the latest projections, the BLS has not only estimated employment growth for all occupations and industries in the economy, but also employment growth within both high-tech industries and high-tech occupations. The BLS defines three groups of high-technology industries (Riche, Hecker, and Burgan 1983, Table 1). The first group consists of industries in which the proportion of technology-oriented workers is at least one and a half times the average for all industries. This standard identifies 48 high-tech industries. The second group, based on the most restrictive definition, assumes that an industry meets the high technology criterion if its ratio of R & D expenditures to net sales is at least

twice the average for all industries. Only six industries meet this criterion: drugs; office, computing, and accounting machines; electronic components and accessories; miscellaneous electrical machinery; aircraft and parts; and guided missiles and space vehicles. The third group consists of industries having a combination of technology-oriented workers greater than the average for manufacturing industries and a ratio of R & D to sales at about the average of all industries. This standard encompasses some 28 industries.

Regardless of the definition, high-technology industries currently employ only a small fraction of the total work force and they will continue to employ a small fraction in the future. Even the largest grouping of high-tech industries employed only 13 percent of the workforce in 1982 and will provide only 17 percent of the new jobs in the period between 1982 and 1995 (Table 3). Employment in these industries is projected to grow only somewhat faster than employment overall (35 versus 28 percent). More restrictive definitions indicate that high-technology industries will provide only 3 to 8 percent of the new jobs in the future economy.

Not only do high-tech industries employ only a fraction of the nation's workers, but many of the jobs they do provide require little or no knowledge of high technology. High-technology industries produce products or services which require large numbers of clericals, secretaries, assemblers, warehouse personnel, and so on. It is the production and distribution of high-technology goods and services that provide the sales revenues and profits, and these functions require far more personnel than the research and development functions.

In the electronic components industry, for example, only about 15 percent of workers were employed in engineering, science, and computer occupations in 1980 (Riche, Hecker, and Burgan 1983, Table 3). The majority were assigned to low-wage assembly work. In 1977 almost two-thirds of the workers in that industry received hourly wages that placed them in the bottom third of the national distribution (Applebaum 1983, p. 10). Even in computer and data processing services--virtually a

prototype of a high technology industry--only 26 percent of the jobs were technologically oriented in 1980.

Of course in particular states and regions the concentration of high-technology industries may be higher or lower than the national average. In fact, the distribution of high-technology employment is very uneven around the country. Based on the third grouping, for example, 33 percent of the work force in the San Jose, California area was in high technology industries in 1980 compared to only 3 percent in Detroit (Riche, Hecker, and Burgan 1983, Tables 5 and 7). But even where employment in high-technology industries is high, only a small proportion of the jobs are in high-technology occupations.

The BLS defines high-tech occupations as those jobs requiring an "in-depth knowledge of theories and principles of science, engineering, and mathematics underlying technology" (Riche, Hecker, and Burgan 1983, p. 54). The occupations that meet this definition are engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists. This group excludes other occupations, such as computer operators and computer service technicians, where workers use or repair sophisticated technological products, but do not require extensive technical competence to fulfill their duties. The BLS definition does include technicians, jobs which require no more than an Associate Degree from a community college, so the overall definition of a high-technology occupation is not restricted to graduates of four year colleges.

According to the BLS definition, only 3 percent of all employment in 1982 was in high-tech occupations (Table 3). Employment in high-tech jobs is expected to increase by 46 percent between 1982 and 1995, but will still only account for 6 percent of the new jobs in the economy. Even these figures may overstate the need for high-level technical skills in the future job market. Many so-called high-tech jobs have been subject to the same fragmentation of job tasks and "deskilling" that have pervaded other sectors of the economy.

Consider the case of computer programming. Early computer programmers, working in machine languages, had "to be comfortable with

abstract logic, mathematics, electrical circuits, and machines, as well as some substantive field, such as aerodynamics or cost accounting" (Kraft 1979, p. 4). But soon programming was divided into several occupations--systems analysts, software designers, and applications programmers--each with different tasks and requisite training. As machines became more powerful, computer software evolved from machine languages, to high-level languages (e.g., FORTRAN), to simpler languages, to software packages that required only following menus. New developments in structured programming have meant that many programmers now perform standard, routine, machine-like tasks that require little in-depth knowledge (Kraft 1979, pp. 10-11). The latest micro-computers can be used without programmers altogether because of more sophisticated "user-friendly" software.

If high tech will provide only a fraction of the future jobs, which jobs will provide the most opportunities in the future economy? A common fallacy is to assume that job categories with the fastest relative or percentage growth rates will offer the most new jobs. According to the BLS projections, however, most new jobs will be found in the older, slower growing occupations where relatively smaller percentage increases amount to very large numbers of jobs. The rapidly growing job categories tend to be in occupations with relatively few people so that large percentage increases amount to relatively few new jobs. It is the absolute expansion of employment within occupations, not occupational growth rates, that will determine the distribution of new opportunities.

To illustrate, the 10 occupations projected to grow most rapidly between 1982 and 1995 are shown in the upper part of Table 4. Many of the fastest growing jobs in the economy are either high-tech jobs, according to the BLS definition, or are directly related to the use of high-tech equipment. Eight of the 10 fastest growing occupations involve the production, use, or repair of computers. Employment in these 10 occupations is expected to increase 76 percent between 1982 and 1995, a rate three times faster than the average growth rate for total employment.

Most of the fastest growing occupations require postsecondary education. Persons working as computer systems analysts, computer programmers, and electrical engineers in 1980 generally had completed at

least 4 years of college . Workers employed in 5 additional fast-growing occupations had completed 1 to 3 years of postsecondary schooling. Most of these jobs also pay above-average wages. The average weekly earnings in 1979 of workers in 6 of the 10 fastest-growing occupations were significantly higher than the average weekly earnings for all workers in the economy. Earnings for the 10 fastest-growing occupations together were 26 percent higher than average earnings in 1979.

According to these figures, many of the occupations experiencing the fastest growth will be in fields related to high tech. Most of those jobs have required postsecondary schooling, and most have paid above average wages. Yet these occupations will provide only 1 million new jobs, less than 4 percent of all the new jobs that will become available in the 1982-95 period.

Table 4 also shows the 10 occupations with the fastest absolute growth, those occupations expected to add the most new jobs to the economy. The 10 categories with the fastest absolute growth represent over six million jobs or nearly one-quarter of all new jobs that are expected between 1982 and 1995. The occupations that will provide the greatest number of new jobs are building custodians, cashiers, secretaries, clerks.

The 10 occupations with the fastest absolute growth differ substantially from those with the fastest rate of growth. None are related to high technology. Only two--nurses and teachers--require any postsecondary education. And the earnings of workers in these occupations averaged 30 percent below the average earnings of all workers in the economy in 1979 (Table 4). Thus, even though high technology occupations will grow rapidly, they will contribute relatively few jobs to the American economy relative to the low level service occupations that are expected to grow more slowly. Indeed, of the forty job categories expected to account for half of all new jobs, only about 25 percent of the occupations require a college degree (Silvestri, Lukasiewicz, and Einstein 1983, p. 45).

The apparent paradox between the high relative growth rates of high-tech jobs and their relatively small contribution to the overall job

situation can be illustrated using the job category that is expected to grow at the fastest rate--computer service technicians. Although the number of job openings for computer service technicians is expected to almost double between 1982 and 1995, that high growth rate will amount to only about 53,000 new jobs. In contrast, the number of jobs for building custodians is expected to increase by only about 28 percent over that period, but that smaller growth rate is expected to generate almost 800,000 new jobs--about 14 times as many as for computer service technicians.

The message from the BLS figures is clear: not only will high tech rovide few job opportunities in the future economy, but most new jobs ill require no postsecondary schooling and will pay wages significantly 'ower than the average. Earlier BLS projections yielded similar conclusions (Levin and Rumberger 1983).

Alternative Scenarios for the Future

The preceding conclusions regarding the impact of high tech on the future job market were based on one set of projections from the BLS. As pointed out earlier, the BLS currently provides three sets of occupational projections based on alternative scenarios regarding expected economic growth rates, productivity increases, and inflation levels. Other agencies, particularly the National Science Foundation (NSF) and the independent Institute for Economic A~alysis (IEA), have also recently produced occupational projections based on alternative scenarios. The NSF scenarios regard alternative assumptions about expected economic growth rates and military spending levels, while the IEA scenarios are based on alternative assumptions about the diffusion of technology throughout the economy.

Comparing projections from these three agencies suggests that growth rates for some occupations could differ widely from the rates projected by the BLS. The IEA projections show the greatest differences with the BLS, while the NSF projections, based on some of the BLS data, are closer to the BLS figures.

The BLS and NSF figures estimate that both high economic growth rates and high defense expenditures will increase overall employment as

well as employment in particular occupations (Table 5). The NSF projections suggest, for instance, that a combination of high economic growth and high defense spending will increase employment more than 2 percent a year between 1982 and 1987, more than 2 times the employment growth expected from low economic growth and low defense spending. The BLS figures, covering a longer period, show overall employment growth rates falling between the two NSF figures. The IEA projections show a higher employment growth rate than the other two estimates.

The BLS and NSF projections for particular occupations are also quite similar. The biggest discrepancy concerns expected growth rates for drafters. The NSF projections were based on older occupational staffing patterns supplied by the BLS, while the newest BLS projections are based on revised staffing patterns. The current BLS projections show virtually no growth for drafters due primarily to the increased use of CAD equipment.

The IEA projections for some occupations, based on scenarios 2 and 3, differ substantially from the BLS projections. Since the IEA model is explicitly designed to account for the impact of technological change, projections for some occupations show much higher growth rates due to the increased use of technology, while others show much lower growth rates due to displacement by machines. For instance, under the assumption of rapid technological diffusion, the IEA projections suggest that all drafting positions will disappear by the year 2000 (Table 5). The IEA projections also show much lower growth rates for secretaries and bank tellers as word processors and automatic teller machines reduce employment needs in these areas. In contrast, employment for computer programmers is expected to increase more than 10 percent per year over the same period. Yet this projection may be overstated because developments in "user-friendly" software will increasingly allow future computers to be used without programmers.

These different sets of projections--produced by different agencies and based on different models and alternative assumptions--suggest similar trends for the future job market. Occupations related to the increased development, production, and use of new technologies will grow faster than

employment overall, while occupations that can be replaced by machines based on these new technologies will grow slower or decline. What differs among these projections is the speed with which such changes will take place. But again recall that even rapid changes in the growth rates of particular occupations may affect only a small number of jobs.

Conclusions

According to the BLS projections, high tech will not dominate the future job market. Neither high-tech industries nor high-tech occupations will supply many new jobs over the next decade. Instead, future job growth will favor service and clerical jobs that require little or no postsecondary schooling and pay below-average wages. Even among the jobs that are generated in high-tech, many are support-level and production jobs that require little or no in-depth knowledge of technology. The skill requirements of others, such as programming, are being lowered through advances in computer hardware and software.

Alternative projections by the BLS and projections from other agencies suggest similar trends but different rates of growth for total employment and employment within particular occupations. The faster that robots, computers, automatic teller machines, and other technical devices spread through the economy, the greater the impact on employment. This means faster growth rates for occupations associated with the production, use, and repair of these devices, and slower or even negative growth rates for occupations replaced by them.

Faster economic growth will generate more jobs in all occupational areas, while increased military spending will generate relatively more jobs for scientific and technical personnel because military contractors employ between one quarter and one half of the workers in these fields (DeGrasse 1983, p. 101). The IEA projections suggest that the growth rates of many occupations will be affected much more by the diffusion of technology than by economic growth or the growth of military spending. But, it must be stressed that the development and rate of adoption of new technologies in themselves depend heavily upon investment, a factor which is driven primarily by economic growth and to a lesser extent by orders

for new weapons systems.

Technology will not only affect the kinds of jobs available in the future economy, but it will also affect the total number of jobs available and the skill requirements of all jobs. These other two effects have equally important implications.

Consider the impact on the level of employment. It is quite clear that technology creates new jobs and destroys others. Will the net impact of these changes sustain, increase, or reduce employment levels? At least some evidence suggests that more jobs will be destroyed than created by technological change. A recent study of robotics suggests that robots will eliminate 100,000 to 200,000 jobs by 1990, while creating 32,000 to 64,000 jobs (Hunt and Hunt 1983, pp. x-xi). The increased movement of production jobs, even in high-tech electronics, to overseas locations also threatens the level of domestic employment (Bluestone and Harrison 1982, pp. 42-46). The IEA projections suggest that rapid technological diffusion could eliminate 20 million jobs by the year 2000, 11 percent of all the jobs that would exist in the absence of further technological diffusion (Leontiff and Duchin 1983, Table 1.1).

Technology will also have a widespread affect on the skill requirements of future jobs. It is commonly assumed that as more and more workers use computers and other sophisticated, technical devices in their jobs, they will need computer-programming and other sophisticated skills. Yet a variety of evidence suggests just the opposite: as machines become more sophisticated, with expanded memories, more computational ability, and sensory capabilities, the knowledge required to use the devices declines (Levin and Rumberger 1983).

Technology is already having a widespread impact on work and the economy and promises an even greater influence in the future. It could greatly increase the productivity of the American work force and enable this nation to regain its competitive position in the world marketplace. But it could also eliminate jobs and reduce the skills of others. The challenge we face as a nation is to harness the benefits from technology at the same time that we mitigate its potentially negative impact on work and employment.

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Table 1

Employment by Major Industry Group: 1900 to 1995[a]

(percentage distribution)

Industry Group	1900	1930	1960	1980	1995[b]
Agriculture	41	23	8	3	2
Goods-producing					
Mining	2	3	1	1	1
Construction	4	4	5	5	6
Manufacturing	21	24	28	22	18
Services-producing					
Transportation and utilities	9	9	7	6	5
Wholesale and retail trade	10	15	19	22	22
Finance, insur., and real estate	1	4	5	5	6
Services	7	9	12	19	26
Government	4	8	14	17	14

[a]Distributions based on total civilian employment. Nonagricultural employment calculated from data on employees on nonagricultural payrolls, with self-employed and nonpaid family members distributed proportionally among industries.

[b]Data for 1995 based on moderate-trend projections.

Sources: U.S. Bureau of the Census, Historical Statistics of the United States, Part 1 (Washington,D.C.: U.S. Government Printing Office, 1975), Tables D1-10 and D127-141; U.S. Council of Economic Advisors, Economic Report of the President (Washington,D.C. U.S. Government Printing Office, 1983), Table B-29; U.S. Department of Labor, Employment and Training Report of the President (Washington, D.C.: U.S. Government Printing Office, 1981), Table C-1; Valerie A. Personick, "The Job Outlook Through 1995: Industry Output and Employoment," Monthly Labor Review 106 (November 1983), Table 2.

Table 2

Employoment by Major Occupation Group: 1900 to 1995[a]

(percentage distribution)

Occupation Group	1900	1930	1960	1980	1995[b]
Professional and technical	4	7	11	16	17
Managerial	6	7	11	11	10
Clerical	3	9	15	19	19
Sales	5	6	6	6	7
Craft	11	13	13	13	12
Operataive	13	16	18	14	12
Laborer	12	11	6	5	5
Service	9	10	12	13	16
Farm	37	21	8	3	2

[a]Distributions for 1900 and 1930 based on experienced civilian labor force. Distributions for other years based on total employed persons.
[b]Data for 1995 based on moderate-trend projections.

Sources: U.S. Bureau of the Census, Historical Statistics of the United States, Part 1 (Washington,D.C.: U.S. Government Printing Office, 1975), Table D182-232; U.S. Department of Labor, Employment and Training Report of the President (Washington,D.C.: U.S. Government Printing Office, 1979 and 1982), Tables A-16 and A-18; George T. Silvestri, John M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1.

Table 3

Employment and Employment Growth, by High-Tech Industries and Occupations: 1982 to 1995

Industries Occupations	Employment, 1982 (thousands)	Employment growth, 1982-95[a] (thousands)	(percent)
All industries[b]	91,950	25,795	28.1
High-tech industries[c]			
Group I (48 industries)	12,350	4,263	34.5
Percent of all industries	13.4	16.5	
Group II (6 industries)	2,543	867	34.1
Percent of all industries	2.8	3.4	
Group III (28 industries)	5,691	2,029	35.7
Percent of all industries	6.2	7.9	
All occupations[d]	101,510	24,600	25.2
High-tech occupations[e]	3,287	1,508	45.9
Percent of all occupations	3.2	5.9	

[a]Data for 1995 based on moderate-trend projections.
[b]Employment covers all wage and salary workers
[c]Group I includes industries where the proportion of workers employed in high-tech occupations[e] is at least 1.5 times the average for all industries. Group II includes industries with a ratio of R & D expenditures to net sales at least twice the average for all industries. Group III includes manufacturing industries in which the proportion of workers employed in high-tech occupations[e] is equal or greater than the average for all manufacturing industries; two manufacturing industries that provide technical support to high-tech manufacturing industries are also included.
[d]Employment covers all civilian workers
[e]Engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists.

Source: Richard W. Riche, Daniel E. Hecker, and John V. Burgan, "High Technology Today and Tomorrow: A Small Slice of the Employment Pie," Monthly Labor Review 106 (November 1983), Tables 2 and 4.

Table 4

Employment, Employment Growth, Required Education, and Relative Earnings for the Fastest Growing Occupations: 1982 to 1995

	Employment, 1982 (thousands)	Employment growth, 1982-95 (thousands)	(percent)	Required education[a] (years)	Relative earnings[b] (percent)
Fastest relative growth[c]					
Computer service technicians	55	53	97	13-15	129
Legal assistants	45	43	94	13-15	86
Computer systems analysts[d]	254	217	85	16	149
Computer programmers[d]	266	205	77	16	122
Computer operators	211	159	76	12	82
Off. machine repairers	56	39	72	12	106
Physical therapy ass.[d]	33	22	68	12	57
Electrical engineers[d]	320	208	65	16	167
Civil eng. techs.[d]	35	23	64	13-15	121
Per. EDP equip. opers.	49	31	63	13-15	73
TOTAL	1,324	1,000	76	--	126
Fastest absolute growth[e]					
Building custodians	2,828	779	28	<12	69
Cashiers	1,570	744	47	12	49
Secretaries	2,441	719	30	12	67
General clerks, office	2,348	696	30	12	67
Sales clerks	2,916	685	24	12	52
Nurses, professional	1,312	642	49	13-15	90
Waiters and waitresses	1,665	552	34	12	39
Teachers, kind./elem.	1,366	511	37	16	110
Truck drivers	1,604	425	27	12	117
Nurses aides and orders.	1,218	423	35	12	58
TOTAL	19,268	6,186	32	--	70
All occupations	101,510	25,600	25	--	--

[a] The level of education completed by the majority of workers employed in each occupation during the spring of 1980.
[b] The average weekly earnings during 1979 of workers in each occupation relative to the average weekly earnings of all workers.
[c] Based on the greatest percentage increase.
[d] High-tech occupations as defined by the BLS.
[e] Based on the greatest increase in the number of new jobs.

Sources: George T. Silvestri, Johon M. Lukasiewicz, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1; Calculations based on the 1980 Public Use Sample, U.S. Bureau of the Census.

Table 5

Projected Average Annual Growth Rates for Total Employment and Employment in Selected Occupations: 1978 to 2000

Agency: Period Scenario	Total Employment[a]	Selected Occupations				
		Electrical Engineers	Drafters	Computer Programmers	Secretaries[b]	Bank Tellers
BLS: 1982-95						
1. Low growth	1.6	4.0	0.2	4.4	1.5	1.9
2. Moderate growth	1.7	3.9	0.4	4.5	1.6	2.0
3. High growth	1.9	4.1	0.6	4.6	1.8	2.1
NSF: 1982-87						
1. Low growth/low defense	1.0	3.9	1.6	4.3	---	---
2. Low growth/high defense	1.3	4.8	2.2	4.6	---	---
3. High growth/low defense	2.1	4.0	2.6	4.6		
4. High growth/high defense	2.4	5.1	3.3	5.0	---	---
IEA: 1978-2000						
1. No technological diffusion	3.2	3.2	3.4	3.6	3.3	3.2
2. Moderate technological	2.9	3.2	-2.8	10.5	2.0	0.8
3. Rapid technological change	2.6	4.0	-16.8	11.7	0.1	-0.9

[a] Definitions of total employment vary slightly among projections.
[b] Includes secretaries, stenographers, and typists.

Sources: George T. Silvestri, John M. Lukasiewica, and Marcus E. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1; National Science Foundation, Projected Response of the Science, Engineering, and Technician Labor Market to Defense and Nondefense Needs, 1982-87 (Washington,D.C.: U.S. Government Printing Office, 1983), Tables B-1-B-8; Wessily Leontief and Faye Duchin, "The Impacts of Automation on Employment, 1963-2000," Institute for Economic Analysis, New York University, September 1983, Table 11 and unpublished figures supplied by David Howell.